Effect of location and season on body and testicular growth in Brahman and Hereford bulls

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EFFECT OF LOCATION AND SEASON ON BODY AND TESTICULAR GROWTH IN BRAHMAN AND HEREFORD BULLS[1,2,3,4,5]

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ABSTRACT

To determine the effects of location and season on growth of bulls, Hereford bulls from Montana (MH; n = 15) and Nebraska (NH; n = 15) and Brahman bulls from Texas and Louisiana (BB; n = 18) were moved to three locations: Montana (MT), Nebraska (NE) or Texas (TX). Each location received 5 NH, 5 MH and 6 BB. Control bulls (not relocated) were maintained at each location. All bulls were pubertal at the time of relocation in May 1984. At 28-d intervals, body weight, hip height, testis length and scrotal circumference were recorded for each bull for 22 mo after relocation. Paired testes volume (PTV) was calculated. Among Hereford bulls, body weights were similar ($P > .10$) in all control and relocated bulls by the end of the study, except that MH bulls moved to TX had lower body weights ($P < .01$). Brahman bulls moved to northern locations had dramatically reduced body weights, compared to control Brahmans kept in TX; body weight of Brahman bulls in MT remained lower ($P < .01$) at the end of the study. Brahman bulls in NE and MT had smaller scrotal circumference and PTV ($P < .01$) than did control Brahmans in TX during the 1st yr after relocation. Relocated BB exhibited marked seasonal fluctuations in testis size, with increases during the summer and decreases during the winter ($P < .01$); seasonal changes were not apparent in control Brahmans in TX. These results indicate that moving Brahman bulls to northern environments reduced body weight gain and caused dramatic seasonal changes in testis size; these effects were more pronounced in Brahman bulls moved to the most northern location.

(Key Words: Breeds, Growth, Environment, Testes, Bulls.)

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Introduction

Scrotal circumference is an important and easily obtained indicator of a bull's breeding potential. Testis weight is related closely to the amount of spermatogenic tissue present in bulls (Coulter and Foote, 1979) and is correlated highly with scrotal circumference (r =

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.95; Coulter, 1980). Due to this close relationship, scrotal circumference can be used to predict the amount of sperm producing tissue a bull possesses. Scrotal circumference can be affected by several factors, including breed type. In the U.S. beef cattle industry, *Bos indicus* cattle are thought of and used as a breed type rather than a separate species of cattle. Brahman bulls less than 3 yr old have smaller scrotal circumference than *Bos taurus* bulls of the same age (Morris et al., 1978; Fields et al., 1982; Ruttle et al., 1984). Despite this breed type difference, values for scrotal circumference at puberty are similar between *Bos taurus* and *Bos indicus* bulls (Lunstra et al., 1978; Neuendorff et al., 1985). Brahman females exhibit seasonality in their reproductive traits (Randel, 1983), but the effects of season on reproductive traits in the Brahman bull have not been defined clearly.

Brahman cattle are well suited to the subtropical environment of the southern U.S. along the Gulf Coast, whereas *Bos taurus* cattle are better adapted to the more temperate central, northern and western areas. The growing demand for Brahman crossbred cattle throughout the U.S. has placed Brahman bulls into environments that may have detrimental effects on their growth and reproductive function, particularly in locations with colder temperatures and shorter day length during the winter. The objective of this cooperative study was to determine the effect of three different geographical locations (i.e., environments that differed in management practices, climate, temperature and season) on body and testicular growth in young post-pubertal Brahman and Hereford bulls.

Materials and Methods

General. This study was designed to assess the affects of three different geographical locations (Overton, TX; Clay Center, NE; and Bozeman, MT) on body growth and testicular growth in young postpubertal Brahman and Hereford bulls. Hereford bulls from MT, Hereford bulls from NE and Brahman bulls from TX were relocated to each of the other locations and control bulls were kept at each location of origin. Each location utilized management practices and locally supplied feed ingredients characteristic of that location. Bulls at each location were kept in all male groups and were not used for breeding during the study period. All bulls had scrotal circumference greater than 28 cm (i.e., postpubertal; Lunstra et al., 1978; Neuendorff et al., 1985) and averaged approximately 400 kg body weight at the beginning of the study; bulls were assigned at random within breed type to either control (not relocated) or relocated subgroups from each location of origin. Control bulls at the three locations were fed local diets to achieve an average daily gain (ADG) of .6 kg/d through the end of the 1st yr (May 1985) after relocation and then were fed local maintenance diets to achieve an ADG of .1 kg/d through the end of the study (March 1986). Relocated bulls were fed the same diets as control bulls within each location, but the quantity fed was adjusted for all bulls of all breeds at a location on the basis of the ADG in control bulls. All bulls were weighed monthly and quantity of diet fed was adjusted quarterly to achieve the desired ADG in control bull groups. With this design, changes in body weight and testicular growth within relocated bulls should be representative of those changes that occur in young Brahman and Hereford breeding bulls when moved to different geographical areas of the U.S.

Animals. Age, body weight and testes size of bulls at the beginning of the study are given in Table 1. Brahman bulls (n = 18) had been donated by producers in Texas and Louisiana and had been acclimated to facilities at Overton, TX, prior to initiation of this study. There were 12 American Grey Brahman and 6 Red Brahman bulls, which were distributed equally to each of the three subgroups of six Brahman bulls. This proportion is representative of the types of Brahman bulls in the breed registry. Brahman bulls averaged 5.2 mo older than Hereford bulls ($P < .01$; Table 1), but they were of similar reproductive maturity (based on testis size). Hereford bulls from Nebraska (n = 15) originated at the USDA-ARS U.S. Meat Animal Research Center in Clay Center. These Hereford bulls were from a population that had been selected to maintain production and growth traits at a level that was average for Herefords 10 to 15 yr ago. Hereford bulls from Montana (n = 15) all came from one ranch near Bozeman. These bulls had some genetic influence of Line-1 Herefords from USDA-ARS at Miles City, Montana.

Locations. All bulls that were assigned to be relocated were moved during a 4-d period in late May 1984. Each location was assigned

TABLE 1. LEAST SQUARE MEANS (± SEM) OF AGE, BODY WEIGHT, HIP HEIGHT AND TESTES SIZE OF BRAHMAN AND HEREFORD BULLS AT THE TIME OF RELOCATION.

Breed and location[a]	No.	Age, mo	Body wt, kg	Hip height, cm	Scrotal circumference, cm	Testis length, cm	Testes volume[b], cc
Montana Herefords							
MT	5	15.5 ± 1.3	401.5 ± 19.3	124.0 ± 1.9	32.1 ± 1.1	11.2 ± .5	460.2 ± 44.4
NE	5	15.7 ± 1.3	361.5 ± 19.3	122.8 ± 1.9	30.8 ± 1.1	9.9 ± .5	377.0 ± 44.4
TX	5	15.6 ± 1.3	374.5 ± 19.3	123.3 ± 1.9	32.7 ± 1.1	11.1 ± .5	471.7 ± 44.4
Subtotal[c]	15	15.6 ± .8[d]	379.2 ± 11.1[d]	123.4 ± 1.1[d]	31.9 ± .6[de]	10.8 ± .3	436.3 ± 25.6
Nebraska Herefords							
MT	5	14.1 ± 1.3	429.7 ± 19.3	121.1 ± 1.9	34.1 ± 1.1	11.2 ± .5	518.8 ± 44.4
NE	5	14.0 ± 1.3	401.5 ± 19.3	122.3 ± 1.9	32.4 ± 1.1	9.7 ± .5	420.9 ± 44.4
TX	5	14.2 ± 1.3	418.9 ± 19.3	122.6 ± 1.9	33.0 ± 1.1	11.9 ± .5	497.1 ± 44.4
Subtotal[c]	15	14.1 ± .8[d]	416.7 ± 11.1[e]	122.0 ± 1.1[d]	33.2 ± .6[d]	10.9 ± .3	478.9 ± 25.6
Brahmans							
MT	6	19.9 ± 1.2	395.8 ± 17.6	136.6 ± 1.8	29.5 ± 1.0	10.9 ± .5	395.4 ± 40.5
NE	6	20.9 ± 1.2	381.4 ± 17.6	136.1 ± 1.8	30.9 ± 1.0	11.2 ± .5	428.6 ± 40.5
TX	6	19.1 ± 1.2	429.5 ± 17.6	136.7 ± 1.8	31.3 ± 1.0	10.7 ± .5	435.7 ± 40.5
Subtotal[c]	18	20.0 ± .8[e]	402.2 ± 10.2[de]	136.5 ± 1.0[e]	30.6 ± .6[e]	10.9 ± .3	419.9 ± 23.4

[a]Location codes are MT = Montana, NE = Nebraska and TX = Texas.

[b]Testes volume = .0396 × (average testis length) × (scrotal circumference)^2.

[c]Combined within breed type across locations.

[d,e]Means within breed type (subtotals) within a column without a common superscript differ ($P < .07$ to $P < .01$).

five Hereford bulls from Nebraska, five Hereford bulls from Montana, and six Brahman bulls from Texas. Diets and intakes at each location are reported on as-fed basis.

In Texas (TX), bulls were kept at the Texas A&M University Agricultural Research and Extension Center in Overton, which is located in eastern TX (32°16′N, 94°59′W; 152 m elevation). The Brahman and Hereford bulls in TX were kept separately in two drylot pens (11.9 m × 53.6 m) from May 1984 through November 1985. At this time, the bulls were placed in one 2.8-ha Coastal bermudagrass pasture. During the study, the bulls were fed a diet of ground corn:cottonseed meal (6:1) at approximately 1% of body weight·head^{-1}·d^{-1}, with water and coastal bermudagrass hay available ad libitum. While the bulls were in drylot, they had access to shades, with an equal amount of shade per head (2.3 m^2 per bull).

In Nebraska (NE) the bulls were kept at the USDA-ARS, R. L. Hruska U.S. Meat Animal Research Center in Clay Center (40°32′N, 98°9′W; 550 m elevation). The bulls were kept together in a single brome pasture (4.1 ha) from May through November 1984. While on this pasture, the bulls were fed alfalfa hay as needed to supplement roughage intake due to an extremely dry summer and fall, which decreased the amount of forage available. Beginning in September 1984, bulls were fed 9.1 kg·head^{-1}·d^{-1} of a 1:1 mixture of haylage and corn silage. In late November 1984, the bulls were placed in a 5.8-ha brome pasture with access to a shelter (7.6 m × 24.5 m × 3.7 m, L × W × H) and were fed 15.9 kg·head^{-1}·d^{-1} of the silage mixture. This was increased to 20.5 kg·head^{-1}·d^{-1} in January 1985. In May 1985, the bulls were placed in a 10.1-ha brome pasture without supplemental feed. In August 1985, the bulls were returned to the 5.8-ha pasture with shelter and fed 19.5 kg·head^{-1}·d^{-1} of the silage mixture for the remainder of the study.

In Montana (MT) the bulls were kept at Montana State University in Bozeman (45°40′N, 111°9′W; 1,455 m elevation). All bulls were maintained as one group in a drylot pen (45.7 m × 18.3 m) through June 1984 and fed 1.4 kg·head^{-1}·d^{-1} of cracked barley with chopped hay available ad libitum. In July 1984, the bulls were moved to a 5.1-ha pasture of mixed grasses. In October 1984, the bulls were returned to the drylot pen and fed 3.6 kg·head^{-1}·d^{-1} of cracked barley. The pen had an open-front shed at one end to provide shelter. In May 1985, the bulls were returned to the pasture, where they remained through mid-October. In mid-October 1985, the bulls were placed back in the drylot pen and fed 2.7 kg·head^{-1}·d^{-1} of cracked barley with chopped hay available ad libitum for the remainder of the study.

One Brahman bull in TX was removed from the study in the spring of 1985 due to chronic sinusitis. In MT, two Brahman bulls died of metabolic acidosis during November 1984. These bulls accidentally gained access to a feed storage area and overconsumed cracked barley. In November 1985, a third Brahman bull in MT died of paratuberculosis. Another Brahman bull in MT died of paratuberculosis in January 1986.

Data Collection. At 28-d intervals after relocation, body weight, hip height, scrotal circumference and right and left testis length (**RTL, LTL**) were measured for each bull. Average testis length (**ATL**) was calculated from RTL and LTL. Paired testes volume (**PTV**; Lunstra et al., 1988) was calculated with the formula PTV = .0396 × (ATL) (scrotal circumference)^2. All data were collected for 22 mo after relocation.

Environmental data recorded for the 22 mo period at each location consisted of mean daily temperature, daily windchill index temperature and length of daylight. Each climatological variable was collected on a daily basis and averaged across seasons. Spring was defined as the period from March 21 through June 20. Summer began on June 21 and ended on September 22. Fall began on September 23 and ended on December 20. Winter began on December 21 and ended on March 20. Data from various months within each season were averaged prior to statistical analysis.

Data Analysis. Testes measurements were analyzed by least squares analysis of variance techniques using the General Linear Models (GLM) procedure (SAS, 1985). ANOVA consistent with a split-plot experimental design were utilized. Terms included in the whole plot were breed type and origin (**BTOR**), location (**LOC**) and the BTOR × LOC interaction. The error term was animal within BTOR × LOC. Factors included in the sub-plot were season (**SEAS**) as a measure of time, along with the appropriate interactions (SEAS × LOC, SEAS × BTOR, SEAS × LOC × BTOR), using the

residual as the error term. Body growth (body weight and hip height) was analyzed using a split-plot model with the whole plot the same as that used for testes growth. In the sub-plot, days after relocation (**DAY**), and a quadratic term (**DAY^2**) were included along with the appropriate interactions with BTOR and LOC. Preliminary analyses indicated the body weight change was heterogeneous; therefore, the final analyses included the linear and quadratic terms for DAY within LOC. Parameters associated with body weight change were estimated with this model. Only DAY was significant in preliminary analyses for hip height; therefore, a pooled estimate across BTOR and LOC for the parameter was estimated. Correlation analysis was used to determine Pearson correlations among growth traits within BTOR (SAS, 1985). To determine seasonal patterns of testicular growth, linear contrasts were utilized (SAS, 1985) to compare seasons combined across years.

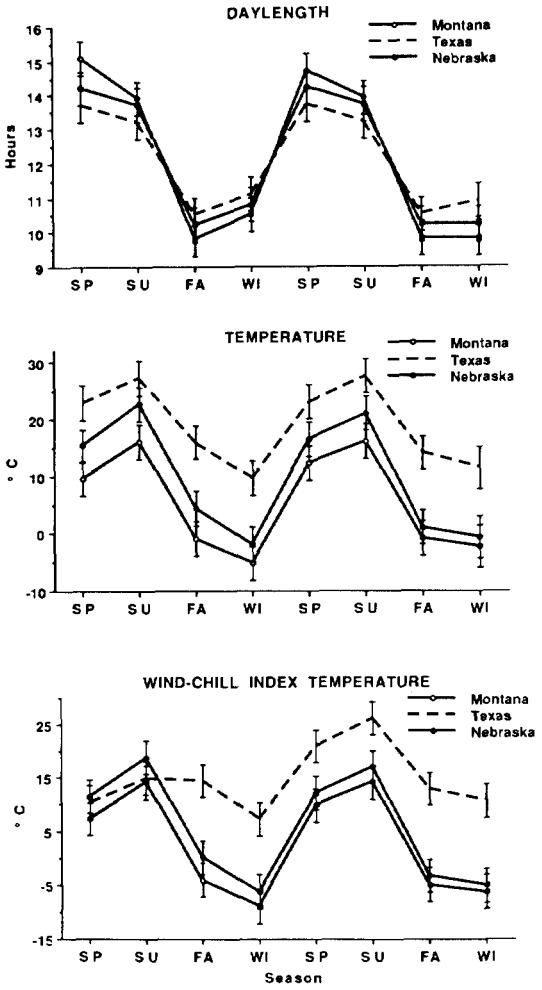

Figure 1. Climatological data at the three locations (Montana, Texas and Nebraska) across season (spring = SP, summer = SU, fall = FA, winter = WI) during the 22-mo study. Temperature = average daily temperature.

Results

Environmental Conditions. Day length was longest ($P < .01$) during the spring and shortest ($P < .01$) during the fall (excluding the final winter, which was incomplete) at all LOC (Figure 1). Texas had the least and MT the greatest amount of fluctuation in day length, and NE was intermediate. Both mean daily temperature and windchill index temperature were higher in TX than in either MT or NE ($P < .01$). Nebraska and MT had similar temperatures during the study, but MT mean daily temperature was colder ($P < .01$) than that of NE when averaged across the entire study.

Body Growth. Body weight of control bulls (not relocated) did not differ ($P > .10$) among LOC or breed type at the end of the 1st yr (spring 1985) of the study; ADG for the 1st yr was .7, .6 and .6 kg/d for control bulls at MT, NE and TX, respectively (Figure 2). During the first 6 mo of the study, bulls in NE, regardless of breed type, grew more slowly ($P < .05$; Figure 3) than did bulls at other LOC, except for Brahmans in MT (Figure 2), reflecting the near-drought conditions in NE during that time. Bulls in NE recovered with supplemental feed during the late fall and winter to achieve a cumulative ADG by the end of the 1st yr in control bulls that was similar to that of the control bulls in MT and TX (Figure 2). All bulls in TX, regardless of breed type, grew more rapidly ($P < .01$) than did bulls at other LOC during the first 9 mo of the study (Figure 3), probably reflecting differences in feeding or the milder temperatures in TX during those fall and winter months (Figure 1). Body weight of all bulls in TX tended to plateau during the 2nd yr of the study as bulls approached mature body weight (Figure 3). Patterns of body weight among Hereford bulls from MT and NE were relatively similar through the end of the study, regardless of final LOC (Figure 2), with the exception of the depressed ($P < .01$) body

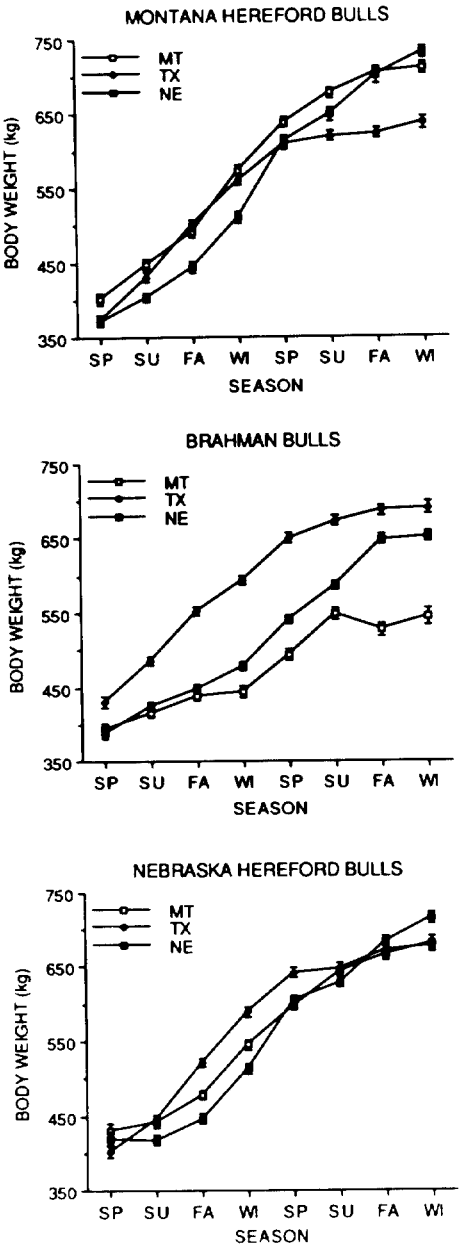

Figure 2. Body weight of Montana Hereford, Texas Brahman and Nebraska Hereford bulls at three locations (Montana = MT, Texas = TX, Nebraska = NE) across season (spring = SP, summer = SU, fall = FA, winter = WI) during the 22-mo study.

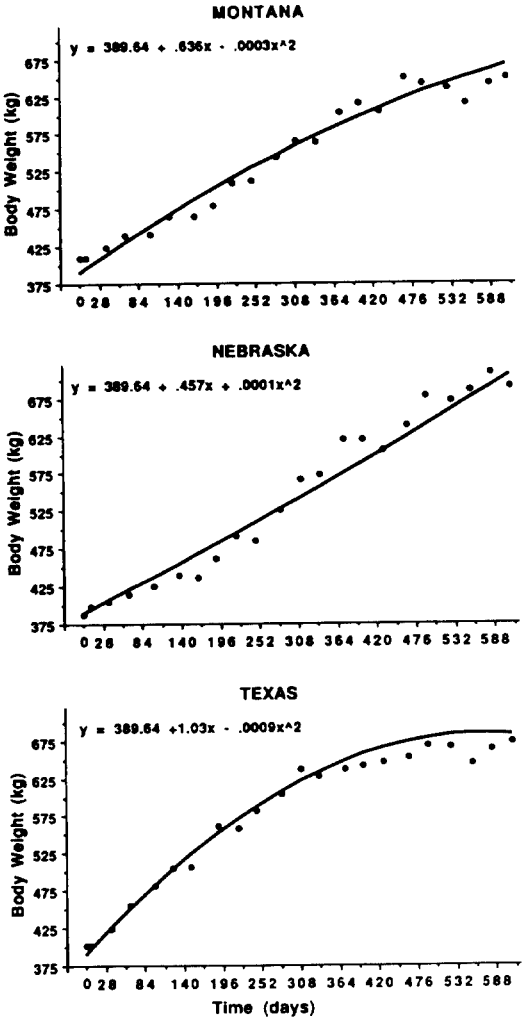

Figure 3. Regression lines for changes in body weight over time in bulls (combined within location; breed type absorbed) at three locations (Montana, Nebraska and Texas) for the duration of the study.

weight during the last 9 mo of the study in MT Herefords that had been moved to TX (Figure 2).

Brahman bulls that had been relocated to more northern environments exhibited dramatic suppressions in body weight gains, compared to body weight of control Brahmans kept in TX (Figure 2). Brahman bulls in NE exhibited depressed growth ($P < .01$) from the first through the second summer of the study (Figure 2), compared to Brahman bulls in TX, but then recovered and grew well during the last fall and winter in NE. This pattern of depressed growth through the second summer of the study was even more pronounced ($P <$

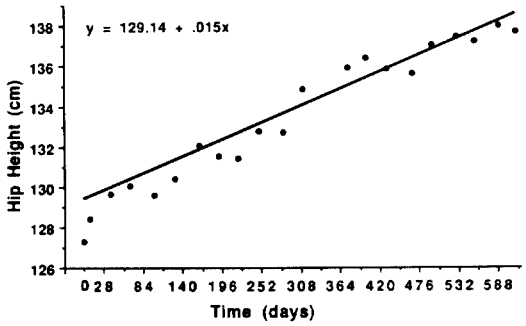

Figure 4. Regression line for changes in hip height over time in all bulls combined across the three locations for the duration of the study.

.001) for Brahman bulls in MT than for those in NE (Figure 2); body weight of Brahman bulls in MT did not increase during the last fall and winter.

Hip height, an indication of skeletal size, increased in a similar ($P > .10$) fashion for all breed types at all LOC; combined data are shown in Figure 4. Mean hip height at the beginning of the study (Table 1) and averaged over the entire study was greater ($P < .01$) in Brahman bulls than in Hereford bulls (both MT and NE combined; 141.7 ± .4 cm vs 129.9 cm, respectively) regardless of location.

Testicular Growth. Control Brahman bulls in TX exhibited a rapid and continuous increase in scrotal circumference (Figure 5) and PTV (Figure 6) during the 1st yr of the study (i.e., through spring 1985); both scrotal circumference and PTV appeared to plateau during the last year of the study in these bulls. However, Brahman bulls relocated to NE and MT exhibited patterns of scrotal circumference and PTV that differed dramatically ($P < .001$) from those in control Brahman bulls. Both scrotal circumference and PTV decreased during the winter and increased during the summer and fall in Brahman bulls relocated to MT and NE (Figures 5 and 6). This seasonal pattern in testis size, present in both the 1st and 2nd yr of the study, was more pronounced during the 2nd yr (Figures 5 and 6), when bulls were more reproductively mature; it was more pronounced for Brahman bulls in MT than for Brahman bulls in NE. Apparently, relocation of Brahman bulls to colder climates with greater seasonal ranges in temperature

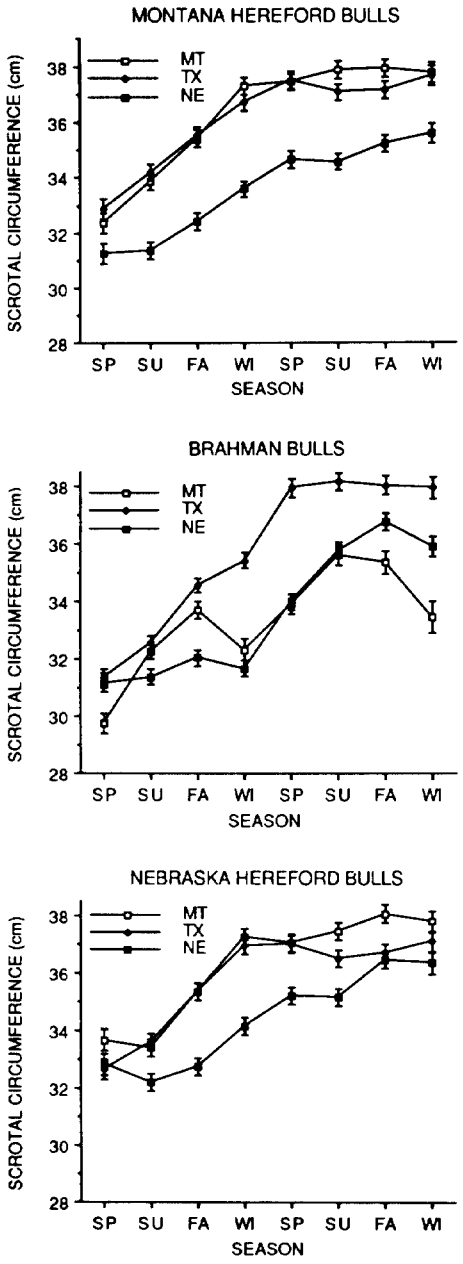

Figure 5. Scrotal circumference of Montana Hereford, Texas Brahman and Nebraska Hereford bulls at three locations (Montana = MT, Texas = TX, Nebraska = NE) across season (spring = SP, summer = SU, fall = FA, winter = WI) during the 22-mo study.

and photoperiod caused dramatic seasonal changes in testis size. Analysis of seasonal changes in testis size using linear contrasts

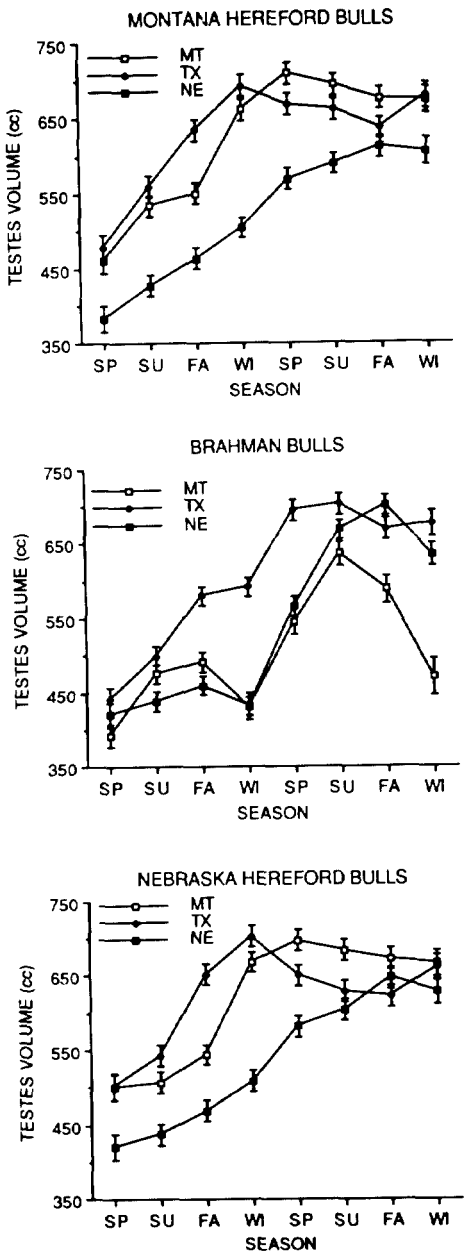

Figure 6. Paired testes volume of Montana Hereford, Texas Brahman and Nebraska Hereford bulls at three locations (Montana = MT, Texas = TX, Nebraska = NE) across season (spring = SP, summer = SU, fall = FA, winter = WI) during the 22-mo study.

confirmed ($P < .0001$) the marked influence of season on scrotal circumference and PTV of Brahman bulls relocated to NE and MT. No consistent seasonal change in testis size occurred ($P > .20$) in control Brahman bulls that remained in TX.

Linear contrast analysis indicated that Hereford bulls (both MT and NE) relocated to TX also exhibited a seasonal pattern in testis size, albeit a less dramatic and different pattern than that observed in relocated Brahman bulls. Both scrotal circumference and PTV were decreased during the summer and early fall and increased during the winter of the 2nd yr in Hereford bulls (both MT and NE) relocated to TX. Although this seasonal effect was not pronounced, the decreased testis size of Hereford bulls moved to TX (Figures 5 and 6) occurred during the hottest months, and the increased testis size in these Hereford bulls occurred during the coolest months of the year in TX (Figure 1).

Control Hereford bulls kept in NE and Hereford bulls relocated from MT to NE exhibited smaller ($P < .01$) testis size (Figures 5 and 6) during the 1st yr of the study than did Hereford bulls at other locations. This reduction in testis growth probably reflected the reduced body growth that occurred during the near-drought conditions of the first 6 mo of the study in NE (Figure 2). During the fall and winter of the 2nd yr of the study, testis size of Hereford bulls in NE tended to increase; PTV of these bulls equalled the PTV of NE Hereford bulls at other locations and nearly equalled the PTV of MT Hereford bulls located in MT and TX (Figure 6). By the end of the study, there were no differences in PTV of Brahman and Hereford bulls ($P > .10$), with the exception of the reduced PTV of Brahman bulls in MT.

Correlation analysis showed that all growth traits were positively correlated with each other in all breed types ($P < .001$; Table 2). Brahman bulls had the lowest correlations between body weight and hip height and between body weight and PTV but had the highest correlations among scrotal circumference, ATL and PTV.

Discussion

The results of this study indicated that Hereford bulls from northern areas adapt in body weight and testis size relatively well to the environment in the South. However, Brahman bulls relocated to northern areas of the country suffered reduced body weight and

TABLE 2. PEARSON CORRELATIONS OF GROWTH TRAITS IN BRAHMAN AND HEREFORD BULLS DURING THE 22-MONTH PERIOD OF STUDY[a]

	Montana Hereford				Brahman				Nebraska Hereford			
	BW	HHT	SC	ATL	BW	HHT	SC	ATL	BW	HHT	SC	ATL
HHT	.73				.44				.82			
SC	.64	.65			.67	.51			.73	.68		
ATL	.46	.41	.40		.37	.39	.64		.40	.33	.40	
PTV	.67	.66	.92	.72	.62	.52	.95	.83	.70	.62	.89	.77

[a]Abbreviations for growth traits are BW = body weight, HHT = hip height, SC = scrotal circumference, ATL = average testis length and PTV = paired testes volume. All correlations were significant ($P < .001$).

testicular development, compared to control Brahman bulls maintained in the South. These detrimental effects on body and testis growth of Brahman bulls appeared to become more pronounced in MT than in NE. By the end of the 2nd yr of our study, body weight and testis size of Brahman bulls in NE approached that of control Brahmans kept in TX. However, body weight and testis size of Brahman bulls in MT remained dramatically lower than that of control Brahmans in TX. This indicated that the Brahman bulls in MT did not adapt completely to the stressful lower temperatures and greater range in photoperiod of the MT environment. Also, this implies that extra emphasis should be placed on nutrition and health management when moving Brahman cattle from the South to northern areas.

The lower scrotal circumference for Brahman bulls compared to Hereford bulls at the initiation of this study agrees with other reports in the literature on young bulls (Fields et al., 1979, 1982; Ruttle et al., 1984). The scrotal circumference of Brahman bulls at the end of the study, with the exception of Brahman bulls in MT, was similar to the scrotal circumference of the Hereford bulls. At the end of the study, the Brahman bulls were 40 mo old and the Herefords were 35 to 36 mo old. At this age, scrotal circumference does not differ between *Bos indicus* and *Bos taurus* bulls reared in the southern U.S. (Morris et al., 1978; Fields et al., 1982; Ruttle et al., 1984).

The testis size of Brahman and Hereford bulls reported in the current study were within the ranges reported in the literature (Morris et al., 1978; Bastidas, 1984; Ruttle et al., 1984). Fields et al. (1979) reported that young Brahman bulls had lower PTV than Florida and Montana Hereford bulls in Florida, which agrees with our data. Fields et al. (1979) also reported that Hereford bulls in Florida showed a decrease in testes volume from April to August. This trend also was apparent during the summer in Hereford bulls relocated to TX in our study.

The testis size was influenced more by season in relocated Brahman than in Hereford bulls. Butts et al. (1971) reported that relocation of cattle to an environment that is extremely different from their native environment can influence both productive and reproductive traits. In their study, Hereford cows from Florida were relocated to Montana, and vice versa. Yearling growth rate of calves was greater for cattle that remained in native environments, and reproductive traits were decreased in cows moved from Montana to Florida (Butts et al., 1971). Rams exhibit seasonal patterns of testicular size, with decreases during the non-breeding season (Mickelsen et al., 1981), but a pronounced seasonal pattern in testis size has not been shown in cattle previously. Brahman females exhibit seasonality in their reproductive cycle, with a decrease in reproductive competence during the winter (Randel, 1983). The seasonal decrease in testis size during the winter in Brahman bulls relocated to more northern areas may indicate reduced reproductive competence in Brahman bulls, also. This is supported further by a decrease in sperm production in Brahman bulls in northern areas of the country during the winter (Godfrey et al., 1990). This implies that use of Brahman bulls for breeding in northern areas of the U.S. should be scheduled during the summer and reduced or avoided during winter months.

Implications

Body and testis growth of Brahman bulls were affected by relocation to northern areas of the country. Intensified health and nutritional management may be required to keep the bulls healthy, and breeding seasons should be

planned to avoid or reduce use of Brahman bulls during winter months in northern locations. It may not be appropriate to move Brahman bulls from the South to the very northern areas of the country, but relocation to the central plains appears less stressful. Subsequent generations of *Bos indicus* × *Bos taurus* crossbred cattle produced in the central plains may be more adaptable to the more northern areas of the country and may be the most appropriate choice for introducing *Bos indicus* germ plasm into northern herds of *Bos taurus* cattle.

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